To: msuplee@mt.gov[]
Cc: []
Bcc: []
From: CN=Tina Laidlaw/OU=MO/OU=R8/O=USEPA/C=US
Sent: Thur 1/17/2013 11:00:01 PM
Subject: Fw: Nearly-final E. Gallatin study plan
EGallatinRiverSpecCriteria_v1.5_FNL.pdf

Mike--- would you mind taking a quick look at this to see if you think it looks ok for me to send to George....? Thanks!

Tina

George --

How about this for a draft email to Amanda and Dave for next week's conference call?

Dave and Amanda,

In preparation for next week's discussion, I thought it would be helpful for you to see a draft of the East Gallatin sampling plan. I asked Mike to work on developing this document to help address the League's concerns with biological confirmation. The purpose of the plan is to clarify DEQ's expectations about what is involved in deriving site specific criteria, specifically for the East Gallatin river. Mike has done a nice job of laying out 2 options: an empirical approach or a mechanistic modeling option. I wanted to make sure the League is aware of our efforts to address these concerns and to incorporate options for addressing them into our larger nutrient strategy. I welcome your feedback on the document and hope it helps alleviate some of your bioconfirmation concerns.

I will email our preliminary Response to Comments document to you before we meet. I apologize for not emailing it to you sooner but I have been very busy with the holidays, our new director and the legislative session starting. Thank you for your patience. I will look forward to getting your input on our draft responses.

Look forward to talking next week.

Tina

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Recommendations for Sampling and Modeling the East Gallatin River to Accomplish Multiple Objectives (v1.5)

Prepared by Michael Suplee, Ph.D.

Water Quality Standards Section, MT Dept. of Environmental Quality, December 27, 2012

1.0 Background

The Department indicated in its draft numeric nutrient standards rule package that a person may collect and analyze water quality and biological data along a reach of stream or river to determine if reach-specific numeric nutrient criteria different from those of the Department are warranted. A draft proposal of this type was provided to the Department in July 2012 for the East Gallatin River (HDR Engineering, 2012)[1]. The Sampling and Analysis Plan (SAP) provided to the Department in July 2012 (HDR Engineering, 2012) is based on sites that were sampled in 2009-2010 for the purpose of determining flow-stage relationships in the East Gallatin River. Building on those sites, the following are recommendations for an optimized study design which can be used to develop reach-specific nitrogen and phosphorus criteria for the East Gallatin River. It is hoped that this document may also serve as a blueprint for similar work that may be carried out on other Montana rivers or streams.

The Department already has a public-reviewed and finalized assessment methodology for determining when a stream reach is impaired by excess nitrogen and phosphorus (Suplee and Sada de Suplee, 2011). However, that assessment methodology was designed to be a minimum data method and was not intended to be sufficient for deriving reach-specific criteria. Therefore, the reader will find that methods recommended below are more data intensive than those needed to complete an assessment via the assessment methodology.

1.1 Design and Possible Outcomes of the Investigation

The East Gallatin River is an excellent case study in which to explore several variations on the development of reach-specific criteria. These variations include:

1. The case where a stream reach may have natural factors (e.g. high turbidity, cold temperature, etc.) that suppress benthic algae growth, and therefore reach-specific criteria are appropriate;

2. The case where benthic algae is found to be above nuisance levels, but modeling shows the algae problem can be addressed by focusing on the reduction of one nutrient more than the other; or

3. The case where reach-specific numeric nutrient criteria for a reach of the East Gallatin River are appropriate, but consideration of downstream beneficial uses precludes their application.

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[1] It should be noted that the Department has developed reach-specific criteria for the East Gallatin River using approaches somewhat different than those provided here. See Section 4.0 in Suplee and Watson (2012).

Figure 1-1 below forms the basis for the recommendations in the rest of this document.

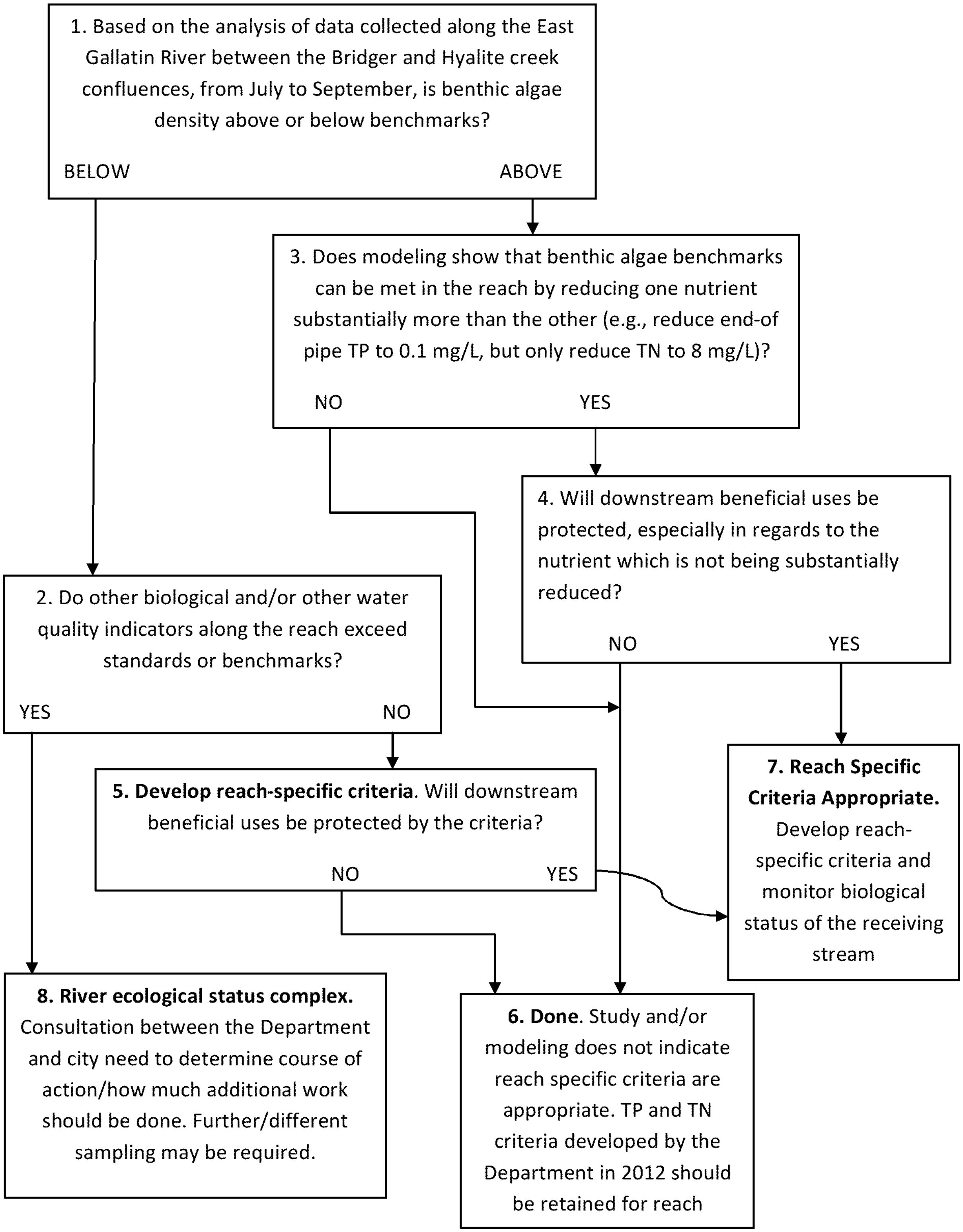

Figure 1-1. Flowchart outlining various outcomes from the analysis of reach-specific data and the development of reach-specific criteria.

Figure 1-1 provides for an empirical approach to developing reach-specific criteria and assessing downstream effects of these criteria. It provides a mechanistic model approach (starting in Box 3), as well as an approach where either option can be pursued (starting in Box 5). Regardless of which approach is taken, as shown in **Figure 1-1,** proper biological characterization of the mainstem East Gallatin River needs to be undertaken. Both criteria derivation approaches require robust field data and an understanding of the impairment status of the river in relation to nuisance algae and/or other aquatic life.

Please note that "other water quality indicators" (Box 2) in **Figure 1-1** does not include a comparison of measured nutrient concentrations to currently recommended criteria for the reach. (That would be circular.) It does, however, include things such as pH, DO, and DO delta; i.e., effect variables. It is a foregone conclusion (based on existing data) that much or all of the reach below the Bozeman water reclamation facility (WRF) outfall will manifest nutrient concentrations in excess of the Department's recommended criteria.

Figure 1-1 does not provide closure in all circumstances. There is a pathway by which one can arrive to Box 8 "River ecological status complex". If the study findings lead to this outcome, it is not clear at this point what the path forward would be. It may require substantially more sampling and analysis. The assumption here is that the Department and the city would want to discuss what (if any) further work would be carried out, and what the endpoints might look like.

1.2 Summary of the Basic Approaches to Reach-specific Criteria

Two broadly defined modeling approaches to developing criteria (empirical and mechanistic) are detailed in the following sections. Briefly, the basic characteristics and strengths and weaknesses of each are given below.

Empirical Approach. Fewer overall sites to sample compared to mechanistic modeling and, as a result, lower overall cost. Samples can be collected most years during baseflow. Samples need to be collected for at least three years, however two of those three years are already needed for the basic biological characterization of the reach and the same sites can be used for both. Robustness of the empirical statistical relationships are difficult to know in advance and could require additional data beyond three years. The ability to run "what if" scenarios or extrapolate predictions outside of the range of data from which the relationship is developed is much more limited compared to that of the mechanistic model.

Mechanistic Approach. This method requires more overall sites and more complex data collection compared to the empirical approach, with concomitantly higher cost. The mechanistic model still requires a two-year biological characterization, only some sites of which will overlap with the sampling sites for the model. The model will also require collection of DO, pH, etc. with deployed water-quality sondes. As you can imagine, these factors increase the cost and complexity of this approach. Data for calibration and validation of the model can be collected during one field season, provided that both collections are done near to peak growth and approximately a month apart. Perhaps two separate low-flow years of data is a better corroboration of the model. Preferably, data collection should occur during a low baseflow (i.e., near the seasonal 14Q5 or, optionally, when baseflow is below the long-term seasonal average). This ensures that physical and biogeochemical conditions are consistent with that of the targeted low-flow period. Once the model is corroborated (i.e., validated) it can readily be used to run "what if" scenarios which can assess downstream uses, different nutrient reduction strategies at the Bozeman WRF and their effects, etc.

2.0 Biological Characterization of the East Gallatin River, and the Empirical Model Approach to Deriving Reach-specific Criteria

<u>Objective 1:</u> Determine the current biological condition of the reach of the East Gallatin River between the Bridger Creek and West Gallatin River confluences during the growing season (summer and early fall) and compare the results to standards and benchmarks used to assess stream eutrophication.

2.1 Detailed Consideration of the Objective 1

The following questions are designed to address objective 1 given above:

In the wadeable regions of the East Gallatin River between the Bridger Creek and West Gallatin River confluences, during the July 20 to September 30 period, what:

(a) are the average benthic algae densities (quantified as chlorophyll a and ash free dry mass, per m^2)?

(b) is the areal coverage and thickness of benthic algae and macrophytes (based on standardized visual assessment methods)?

(c) is the range and central tendency of specified macroinvertebrate metric scores (MT Hilsenhoff Biotic Index, O/E, and EPT taxa richness)?

(d) is the range and central tendency of specified diatom metric scores (WEMAP MVI and WEMAP WA TN)?

(e) are the dissolved oxygen concentrations and pH compared to state standards, and what is the dissolved oxygen delta (daily maximum minus the daily minimum)?

(f) are the concentrations of nitrogen and phosphorus (total and soluble) and total suspended solids?

(g) is the stream temperature, and incoming light intensity(in PAR units, e.g., µmol quanta/$m^2 \cdot s$)?

(h) are the concentrations of herbicides which are frequently used in the watershed?

Note in the question at the start of **Section 2.1** the dates during which data collection should occur (July 20 to the end of September). These dates were based on the Middle Rockies growing season (Suplee et al., 2007), and the fact that in the East Gallatin River the first three weeks of July have considerably higher flows compared to August and September (shown in dark gray, **Table 2-1**). Commencing July sampling after July 20th will generally exclude the higher flows and lead to data collection during base flow conditions more consistent with August and September. Sampling could extend into the first two weeks of October, if temperatures remain moderate and base flow conditions remain reasonably stable (Suplee and Sada de Suplee, 2011).

Table 2-1. Discharge, ft^3/sec for USGS Station 06048700 "East Gallatin River at Bozeman, Mont.". Mean of daily values for 10 years of record (calculation period 2001-10-01 to 2011-09-30).

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	42	47	45	118	283	433	164	52	43	40	55	47
2	44	43	44	128	267	441	155	51	42	41	55	47
3	44	42	46	124	268	453	147	53	39	42	57	47
4	41	43	48	112	297	433	142	53	37	44	56	47
5	43	44	47	121	295	418	141	51	39	48	55	47
6	43	47	46	148	328	425	130	52	42	50	53	47
7	41	44	46	139	364	479	124	51	43	51	55	46
8	46	44	52	140	379	461	118	52	41	51	62	43
9	44	42	54	149	376	440	108	54	43	52	60	43
10	42	42	56	157	380	443	102	52	50	52	56	44
11	41	42	58	155	373	513	101	49	45	52	56	46
12	42	42	70	164	373	501	97	46	41	53	56	46
13	43	42	88	182	377	465	94	45	42	52	57	45
14	44	42	88	218	404	436	90	45	42	52	56	45
15	43	41	80	232	439	420	84	47	43	55	52	45
16	42	41	80	212	442	404	81	44	42	59	55	43
17	44	41	81	229	464	390	78	44	44	61	54	42
18	46	41	86	239	484	359	75	47	45	59	53	41
19	51	42	89	235	509	335	73	46	44	59	53	43
20	48	40	88	231	528	310	68	42	44	66	52	44
21	47	41	93	254	523	299	66	41	46	63	49	45
22	44	41	94	279	505	277	66	41	47	58	47	44
23	44	41	94	324	495	264	67	45	48	56	48	46
24	44	41	90	315	500	247	62	43	49	56	46	44
25	43	41	89	290	615	237	63	41	46	57	48	45
26	43	42	95	293	540	228	64	41	43	55	50	46
27	47	43	93	270	502	209	63	39	42	55	48	44
28	46	43	95	266	475	195	61	39	42	55	47	44
29	44	41	91	274	490	183	55	41	42	57	46	46
30	45		97	295	466	175	51	41	44	57	47	44
31	43		104		444		50	43		56		43

To further address the questions posed at the start of **Section 2.1**, it will be necessary to measure a number of physico-chemical parameters; the rationale for measuring each of these is described below. Biological parameters specified in the questions above were selected because they are known to be directly influenced by or significantly correlate with lotic nutrient concentrations. The Department has established benchmarks for most of the physic-chemical and biological variables, and East Gallatin River data can be compared against these (DEQ-7, 2012; Suplee and Sada de Suplee, 2010).

Benthic algae densities (chlorophyll *a* [Chl*a*] and ash free dry mass [AFDM] per m^2). Based on work in the Clark Fork River, statewide public opinion surveys, and a whole-stream dose-response study, the Department is using average Chl*a* levels of 125 to 150 mg/m^2 and 35 g AFDM/m^2 as harm-to-use thresholds for western Montana rivers and streams (Dodds et al., 1997; Suplee et al., 2009; Suplee and

Sada de Suplee, 2011). Algae densities above these levels impact the recreation and aquatic life uses. The Department also has standard visual assessment methods to asses algal and macrophyte density at a coarser scale (WQPBWQM-011, 2011). The general composition, amount, color, and condition of aquatic plants are visually assessed in the field using the Aquatic Plant Visual Assessment Form. This information helps describe the health and productivity of the aquatic ecosystem, records nuisance aquatic plant problems, documents changes in the plant community over time, and can be used to help corroborate the quantitative Chl*a* results.

Macroinvertebrate metrics. The Hilsenhoff Biotic Index (HBI) is included as part of the Department's current eutrophication assessment methodology (see Suplee and Sada de Suplee, 2011). The HBI index was designed to assess biological impacts caused by organic enrichment and eutrophication (Hilsenhoff, 1987). The Department considers HBI scores in the Middle Rockies > 4.0 to indicate an impact to aquatic life (Suplee and Sada de Suplee, 2011). Two other metrics, O/E and EPT richness, were considered during the development of the eutrophication assessment methodology since both metrics correlated significantly to nutrient concentrations (Tetra Tech, 2010); however, for simplicity, only the HBI was retained in that methodology. Nevertheless, it would be of value to include these metrics in this study. The O/E metric evaluates the taxa diversity that was actually **O**bserved compared to an **E**xpected taxa diversity for the location where the sample was collected. The Department uses an O/E ratio of 1.0 to 0.9 as un-impacted; ≤ 0.9 is the harm threshold (i.e., loss of 10% of species). Modest stream nutrient enrichment can actually cause the metric to be > 1.0. A Bray-Curtis Index should be calculated to accompany the O/E to help interpret counterintuitive O/E scores (WQPBWQM-009, 2012). The EPT richness metric was part of older DEQ protocols and has application to intermountain valley and foothill streams. EPT richness values > 14 are considered healthy and this value will decline with water quality impacts (Bukantis, 1998).

Diatom metrics. The Department currently addresses nutrient impacts using increaser diatom taxa metrics which were developed using discriminant function analysis (Bahls et al., 2008, Teply, 2010a and 2010b; Suplee and Sada de Suplee, 2011). Currently there is no calibrated and validated model for the ecoregion in which the East Gallatin River resides (the Department hopes to have such a metric in a year or so). Therefore, two diatom metrics are recommended (one for TN, one for TP) which were developed by others and which correlate closely with stream nutrient concentrations in Montana (Tetra Tech, 2010). The metrics are WEMAP WA TN (for TN) and WMAP MVI (for TP); each was developed from work in the Western Environmental Monitoring and Assessment Program (EMAP) of the early 2000s. Results that differ largely from the regression line shown in Tetra Tech (2010) might suggest a stream with characteristics different from the Middle Rockies norm; for example, a WEMAP MVI diatom score of 1.5 associated with a TP concentration of 0.25 mg/L would be well outside the expected pattern (one would expect a score closer to 3)(Tetra Tech, 2010).

Dissolved oxygen, pH. Standards for dissolved oxygen (DO) and pH for a B-1 waterbody are established in state law (DEQ-7 October, 2012). DO and pH have been linked to elevated nutrient concentrations (Stevenson et al., 2012), making them good parameters to measure. But the Department has frequently observed that DO minima are not found to be out of compliance in heavily eutrophied streams, at least during summer, due to stream re-aeration. However, punctuated DO problems can occur in fall when the built-up algae senesce *en masse* (Suplee and Sada de Suplee, 2011). Therefore, in addition to state-adopted DO standards, the Department uses DO delta (daily maximum minus the daily minimum) of 5.3 as a benchmark for excessive plant productivity and respiration in streams (see Appendix C.2, Suplee and Sada de Suplee, 2011). Others have found DO delta to be valuable in assessing eutrophication in northern rivers, and recommend a benchmark of 5.0 (Minnesota Pollution Control Agency, 2010).

Concentration of nitrogen and phosphorus (total and soluble), total suspended solids, temperature, incoming light intensity, and herbicide concentrations. These water quality parameters are critical for the development of empirical relationships between algae density and nutrient concentrations. Variables that influence light levels are particularly important for algal growth rates. Light measurements can include PAR near the stream bottom, or (as a possible surrogate) measurements of canopy density above the water's surface. Temperature alters the growth rates of stream algae. In addition, stream samples for herbicides which have historically been used in the basin should be collected as these, if present in sufficient concentration, could suppress algal growth. Previous work has shown herbicides to be present in Montana rivers and streams, with atrazine, metolachlor, and triallate being among the most commonly detected (USGS, 2004). Algae (as well as macrophytes) are sensitive to these herbicides and growth can be suppressed at fairly low concentrations (see work by the USGS and EPA at: **http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm#benchmarks, and http://www.cerc.usgs.gov/clearinghouse/data/usgs_brd_cerc_d_cerc008.html** . The Department would not consider suppression of algal growth in the East Gallatin River due to herbicides as a viable rationale for reach-specific nutrient criteria because (a) it is not a naturally occurring environmental variable and (b) future application of BMPs might reduce the amount of herbicides reaching the river and this change could remove the algae-suppressing effect.

2.2 Data Collection Methods

The Department has Standard Operating Procedures (SOPs) for the collection of benthic and phytoplankton algae (both quantitative and qualitative methods)(WQPBWQM-011, 2011), diatoms (WQPBWQM-010, 2011), macroinvertebrates (WQPBWQM-009, 2012), and water quality (WQBWQM-020, 2012), and recommended methods for measuring DO, pH, and DO delta when assessing eutrophication (Suplee and Sada de Suplee, 2011). The Department's 3rd iteration of the Field Procedures Manual (WQBWQM-020, 2012) also summarizes parts of the SOPs most pertinent to field sampling. I recommend these methods be adhered to for all sampling in the East Gallatin River. These documents can be found at: http://deq.mt.gov/wqinfo/qaprogram/sops.mcpx.

A common trait of all the biological sampling methods is the necessity of laying out a short sampling reach, which the Department usually refers to as a 'site'. These short reaches are typically 150 to 300 m in length in wadeable streams, and are delineated at the time of sampling as 40X the wetted width of the stream or a minimum of 150 m. Sample collection at locations where there is a large proportion of the river that is unwadeable requires special consideration and these situations are also addressed in the SOPs.

Collection of DO, temperature, pH, and DO delta are best measured with deployed data sondes (e.g., YSI 6600s). Continuous collection of data via sondes is not needed at all stations but 1 or 2 along the East Gallatin River study reach is recommended for biological characterization. These instruments can be rented seasonally from commercial suppliers.

Details on data collection will need to be elaborated upon in the final Sampling and Analysis Plan (SAP) developed to implement this general study design.

2.3 Recommended Sampling Sites along the East Gallatin River

To address objective 1 and its associated questions, ten sampling sites have been identified along the East Gallatin River between the Bridger Creek and West Gallatin River confluences (**Figure 2-1**). These ten sites are key to the implementation of the empirical approach outlined in **Section 1.2**. Seven sites (A to G; **Figure 2-2**) are intended for more intense chemical and biological sampling, while three (H to J) may be less intensively sampled and are the foundation of the downstream use assessment.

Site A (~0.7 miles downstream of the Bridger Creek confluence, at 45.71516, -111.0358): Establishes water quality and biological conditions near the head of the study reach. Suplee and Watson (2012) indicate that the East Gallatin River upstream of the Bridger Creek confluence should have a higher TP criterion (to account for the natural influence of the Absaroka-Gallatin Volcanic Mountains ecoregion). However, the elevated TP has been diluted out once Bridger Creek joins the river, and the recommended criteria are then the same as for the Middle Rockies as a whole. The site is the natural starting point for the work. This site also corresponds to site 1 of the mechanistic model (i.e., the QUAL2K model).

Site B (~0.3 stream miles upstream of Bozeman WRF outfall, at 45.72568, -111.06469): Provides a second site to characterize the upper extent of the study reach. It is also not far upstream from the major point source on the river and so can provide a nearby point of reference for any changes occurring downstream of the facility. See also, **Figure 2-3.**

Site C (~0.9 stream mile downstream of the Bozeman WRF outfall, at 45.7284, -111.072): First site downstream of the city of Bozeman WRF discharge. A study shows that the facility's effluent is completely mixed within about 400 ft (0.08 miles) of the discharge (USGS, 1999), although flows at the time of the study were nearly double that of average conditions and nearly 3X the 7Q10. This site—located about 0.9 miles downstream of the discharge— should capture changes in the river due to the effluent, post-mixing. See also, **Figure 2-3.**

Site D (~0.3 stream miles downstream of the Riverside Water & Sewer District ponds, at 45.7363, -111.07105): Conversations with Department staff indicate that the Riverside Water & Sewer District ponds are a likely source of nutrients to the East Gallatin River. By establishing this site (and the one upstream, site C) it should be possible to discern differences in river biology and water quality due to the Bozeman WWTP effluent vs. any subsequent changes due to the ponds. See also, **Figure 2-3**. This site also corresponds to QUAL2K model site 2.

Site E (~0.6 stream miles downstream of the Buster Gulch irrigation diversion, at 45.74765, -111.08195): Site is established below a major water withdrawal to Buster Gulch. The site is established in order to determine if lower water volume is having a measureable effect on water quality or biology of the reach below the withdrawal.

Site F (Lower third of reach at 45.76698, -111.0968): Site will provide data representative of the reach between site E upstream and site G downstream. There are few notable characteristics in this reach of the river (e.g., point sources, tributaries, etc.) and this site will help ascertain the degree to which upstream loads extend their influence downstream.

Site G (upstream of confluence with Hyalite Creek, at 45.7888, -111.1195 [same as site EGRF2]): Establishes water quality and biological conditions near the end of the reach prior to the Hyalite Creek confluence. This site corresponds to a site established in an earlier study on the river (PBS&J, 2011). Any earlier data can be compared to that collected for this study. This site also corresponds to QUAL2K model site 3.

Site H (just upstream of the Dry Creek Irrigation withdrawal, at 45.83059, -111.14617): Nutrient criteria recommended for Hyalite Creek are higher for TP (due to natural geologic sources) and slightly lower for TN (to maintain N limitation) than the reach of the East Gallatin River into which Hyalite flows (Suplee and Watson, 2012). As such, Hyalite Creek is an important water quality change point. This site is intended to discern changes resulting from Hyalite Creek and to characterize the East Gallatin just prior to the Dry Creek irrigation withdrawal. This location is the first site intended for the assessment of downstream uses. This site also corresponds to QUAL2K model site 4.

Site I (just upstream of the Dry Creek Irrigation System return flow, at 45.88921, -111.26408): The Dry Creek Irrigation system is one of, if not the largest, irrigation withdrawals on the East Gallatin River. Irrigation return flows can be a significant source of nutrients and turbidity. The intent of this site is to characterize the East Gallatin River just prior to the addition of irrigation return flow to the river. The site is part of the assessment of downstream uses, and also corresponds to QUAL2K model site 5.

Site J (just upstream of the confluence with the West Gallatin River, at 45.8923, -111.3286 [same as site EGRF1]): This site is located just upstream of the confluence with the West Gallatin River, and should reflect effects from the Dry Creek irrigation return. The site corresponds to an earlier study site (EGRF1; PBS&J, 2011) and so flow-stage relationships established there can be used; it also is the end of the study reach. The site is part of the assessment of downstream uses, and also corresponds to QUAL2K model site 6.

If resources are a constraint, objective 1 can be addressed with a scaled-down version of this plan. At a very minimum, the Department recommends that sites B, C (or as alternate to C, D), F, G, H, I and J be sampled.

2.4 Sampling Frequency and Duration of Study

Each site should be sampled synoptically at least once during the months of July, August, and September. This will provide good characterization of the sites during baseflow. Two years of data should be collected for the basic biological characterization. This will provide enough information to have some confidence in the biological status of the river during baseflow. If it is intended that the empirical criteria-derivation approach is taken, at least one more year (three total) of baseflow data should be collected at the sites. (Requirements associated with the mechanistic model approach are addressed in **Section 3.0**.) However, if a particular year has unusual high flows ≥ 165% of the long-term average August and September flows, data should not be collected until flows have declined to below this volume. At the USGS gage station at Bozeman on the East Gallatin River (gage No. 06048700), the long-term average flow in August and September is 45 ft^3/sec; thus, until summer and fall flows fall below 74 ft^3/sec, sampling should not occur.

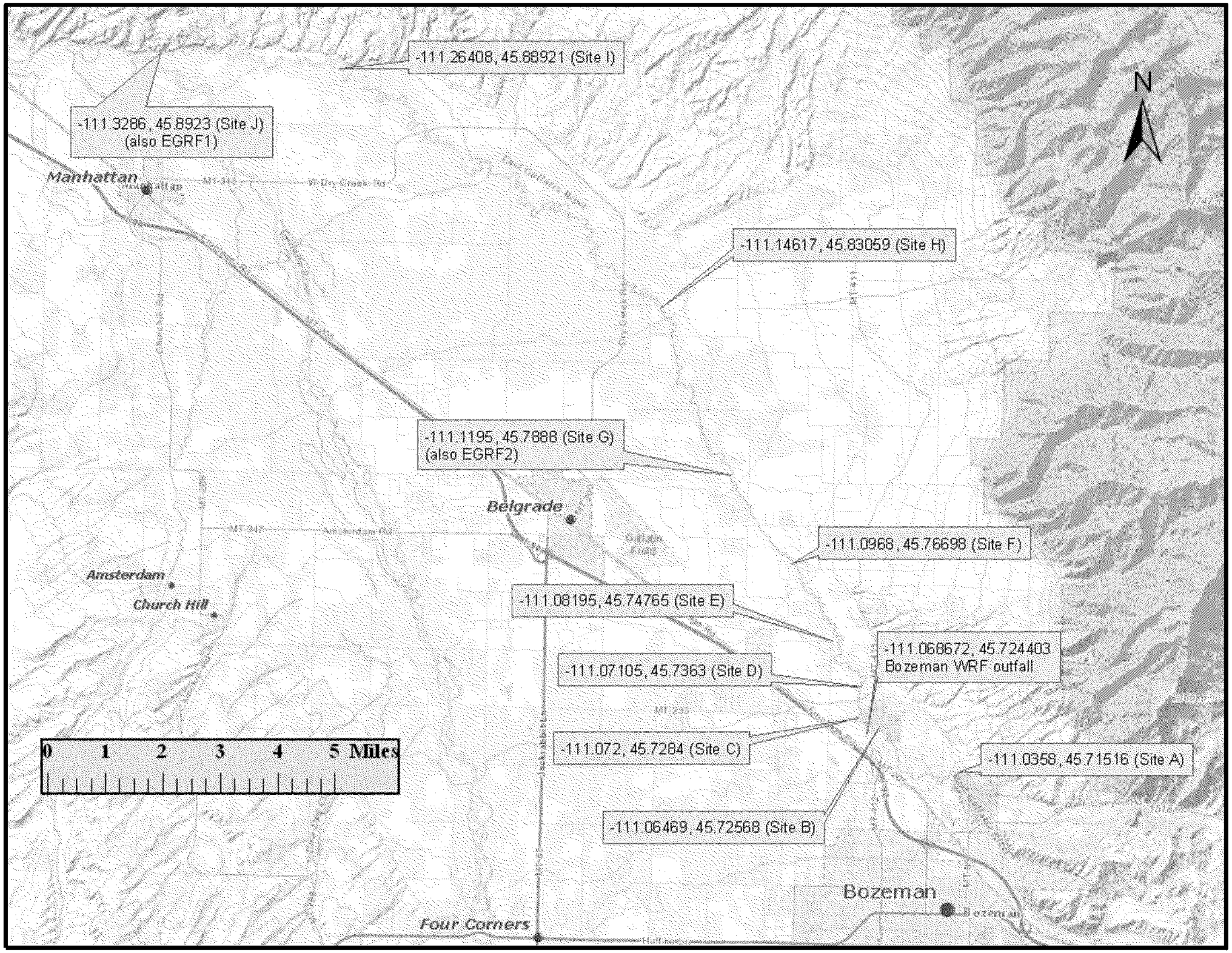

Figure 2-1. Ten biological and water quality sampling sites along the East Gallatin River. Sites A to G are for biological characterization of the East Gallatin River in the reach below the WRF. Sites H to J are for biological characterization <u>and</u> for assessing downstream use protection.

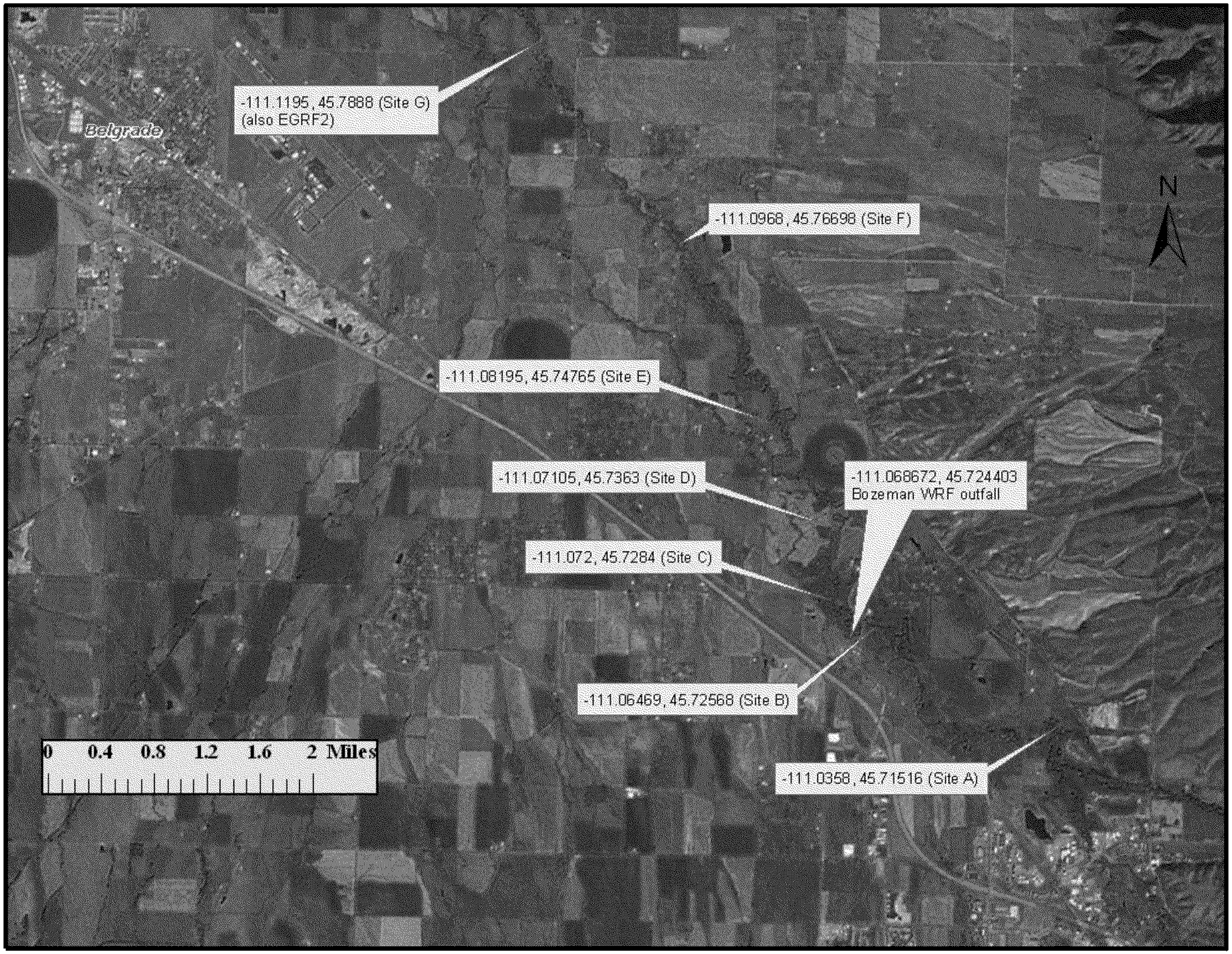

Figure 2-2. Sampling sites A to G along the East Gallatin River between the Bridger and Hyalite creek confluences.

Figure 2-3. Close-up of the three sampling sites around the city of Bozeman WRF discharge. Green dot is USGS gage 06048700.

2.5 Data Analysis and Interpretation

Due to the number of variables measured (e.g. benthic algae density, macroinvertebrates, diatoms), many different data combinations and outcomes are possible. The Department does not believe that establishing a rigid analysis structure upfront—that is, laying out the exact statistical tests, data aggregation methods, etc.—would be beneficial at this point. There are still a number of unknowns going forward and we must allow ourselves some flexibility in how the data will be interpreted. When statistical tests are, ultimately, carried out, a balance should be sought between type I and II error rates, as has been instituted in other Department stream-assessment procedures (Suplee and Sada de Suplee, 2011). This will seek a balance between error that imposes unneeded cost on the regulated community, and error that leads to degradation of (or lack of improvement to) the river environment (Mapstone, 1995).

2.6 Reach Specific Criteria—Empirical Approach

If it appears that natural environmental factors are keeping benthic algae density below nuisance levels in spite of elevated nutrient concentrations, then it may be possible to develop a reach-specific multiple regression equation involving nitrogen, phosphorus, and the additional environmental variable(s) of relevance, as has been done by others (e.g., Dodds et al., 1997; Biggs, 2000). Whether there will be enough data to develop significant relationships is hard to predict in advance, especially if the reduced-sites approach is selected; but it is safe to say the dataset will be relatively small and will require the assumption that all (or most) sites are independent from one another and samples collected a month apart are temporally independent. The Department has been able to substantiate similar assumptions in other cases (see Appendix A.3, Suplee and Sada de Suplee, 2011).

The multiple regression might take on the following form (Neter et al., 1989):

$$Y = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_nX_n$$

where Y is the dependent (or response) variable, what is being predicted or explained; β_o is a constant or Y-intercept; β_1 is the slope (beta coefficient) for X_1; X_1 is the first independent variable that is explaining the variance in Y; β_2 is the slope for X_2; X_2 is the second independent variable that is explaining the variance in Y; β_3 is the slope for X_3 and X_3 is the third independent variable that is explaining the variance in Y, and on so on for the total number of slope·variables used (β_nX_n). For purposes of this work, Y equals benthic algae density (mg Chl*a*/m^2, g AFDM/m^2). Likely explanatory variables (βs) would be TN concentration, TP concentrations, TSS concentration, and stream-bottom PAR. This same approach could be used to explain relationships between other response and causal variables (e.g., macroinvertebrate HBI score as the response [Y], TN, TP, and TSS as causal variables [βs]).

2.7 Protection of Downstream Uses

The next step in the process is to determine if downstream uses will be protected by the reach-specific criteria (Box 5, **Figure 1-1**). Nutrients are assimilated longitudinally in streams and elevated concentrations will eventually decline due to biological uptake and adsorption to the sediments. Thus, assessing protection of downstream uses amounts to an evaluation of whether or not the higher nutrient concentrations being allowed upstream will have a deleterious effect downstream.

It is unlikely that any reach-specific criteria in the East Gallatin River would affect the Missouri River. The confluence of the three forks of the Missouri River results in orders-of-magnitude greater summer flows than the East Gallatin River. For example, mean August flow in the Missouri River ~24 miles downstream of the three forks is around 2,747 ft^3/sec, whereas in the Gallatin River at Logan it is 490 ft^3/sec, and near the mouth of the East Gallatin River it is about 250 ft^3/sec (USGS, 2002; PBS&J, 2011). The most likely impacts from reach-specific nutrient criteria would be in the reach of the East Gallatin River downstream of the Hyalite Creek confluence. The nitrogen criterion recommended for the East Gallatin River between Hyalite Creek and the confluence with the West Gallatin River is 290 µg TN/L, lower than the 300 µg TN/L for the Middle Rockies (Suplee and Watson, 2012). Data suggest that the stream is nitrogen limited (since TP is naturally elevated) and is the reason why a lower TN criterion has been recommended there. A relaxation of the nitrogen criterion upstream of Hyalite Creek could very well lead to use impacts if the nitrogen limitation is, consequently, alleviated.

Two approaches (which tie to Box 5 in **Figure 1-1**) can be taken to address downstream effects:

An empirical approach. If the sites along the East Gallatin River downstream from Hyalite Creek (sites H, I, and J) show a general immunity to elevated nutrients (and the reach upstream of Hyalite Creek does as well) due to some natural factor like elevated turbidity, then reach specific criteria in the East Gallatin River could be extended all the way from the Bridger Creek confluence to the confluence with the West Gallatin River, or even beyond, to the confluence with the Missouri River. However if the reach of the East Gallatin River downstream of the Hyalite Creek confluence shows biological impacts/nuisance algae above targets, then reach specific criteria that may be appropriate for the East Gallatin River further upstream will not protect downstream uses, and should not be put in place.

A mechanistic modeling approach using QUAL2K. This approach links to **Section 3.0**. The model would extend the full length of the East Gallatin River, between the Bridger Creek and West Gallatin River confluences to ascertain whether nutrients at a certain concentration, moving downstream from the point where Hyalite Creek confluences with the East Gallatin, would impact the beneficial uses further downstream. Beneficial uses addressed by the model include DO delta, pH delta, and benthic algae density. **Please note that the mechanistic model requires additional types of sampling and sampling sites (tributaries, irrigation withdrawals and returns) than the empirical approach; see Section 3.0.**

The next section discusses approaches that can be used to develop a mechanistic model.

3.0 Developing Reach Specific Criteria via the Mechanistic Modeling Approach

Objective: Collect enough data along the East Gallatin River between the Bridger Creek confluence and the West Gallatin River confluence during a low-flow condition to be able to calibrate and confirm a mechanistic QUAL2K model of the study reach.

This objective still requires adequate biological characterization of the reach, as outlined in **Sections 2.1 through 2.5.** Many sites described in **Section 2.0** overlap with model sites described below; this was done in order to optimize sampling. To assure the reach is long enough to be able to judge the validity of the rate coefficients used in the model, the longitudinal distance must be sufficient to observe during calibration the decline in soluble nutrients, conversions to organic from algal death and recycling, etc. It is the Department's judgment that the East Gallatin River can be effectively modeled if the reach from above the Bozeman WRF to the West Gallatin River confluence (**Figure 3-1**) is considered, a distance of approximately 25 stream miles.

Mechanistic models for criteria derivation require a robust set of field observations including streamflow and water-quality data, measurements from continuously deployed sondes (including, at a minimum, dissolved oxygen, pH, temperature, conductivity, and turbidity), and biogeochemical kinetic observations (if possible). The Department has a detailed Quality Assurance Project Plan (Suplee et al., 2006) and a technical report (Flynn and Suplee, 2011) on the use of the QUAL2K model for developing reach-specific nutrient criteria; the reader is referred to those documents for greater detail. Selected sites are best sampled during one low-flow summer and fall (i.e., a year with flows near the seasonal 14Q5 of the East Gallatin River [McCarthy, 2005] or, alternatively, sequential low-flow summers during the peak of the growing period. Consecutive years with base flows that are below average is preferred but may not always be possible. **If, during the initial biological and water-quality characterization (Sections 2.1 through 2.5), it is found that herbicides are high enough to suppress algal growth, the model will be severely compromised. Therefore, herbicide data are best collected and then assessed in advance of the decision to complete the mechanistic model detailed below.**

3.1 Sites Requiring Water Quality Sonde Deployment

For the QUAL2K model, six sites are recommended (**Figure 3-1**). Sondes could be deployed continuously, or for a week to ten days in middle to late August and then again for another week to ten days in middle to late September, during period of relatively stable flow (or in two sequential Augusts if each has lower-than-average baseflow).

Water quality samples for key model drivers (nutrient concentrations—which include total nitrogen, nitrate+nitrite, ammonia, total phosphorus, and soluble reactive phosphorus; TSS and ISS; alkalinity; hardness; $CBOD_{20}$; Total Organic Carbon [TOC]; and benthic and phytoplankton algae) need to be collected at the six sites, at least once in August and once in September (or in sequential low flow years). These data collections could potentially be synchronized with the data collection in **Section 2.1**.

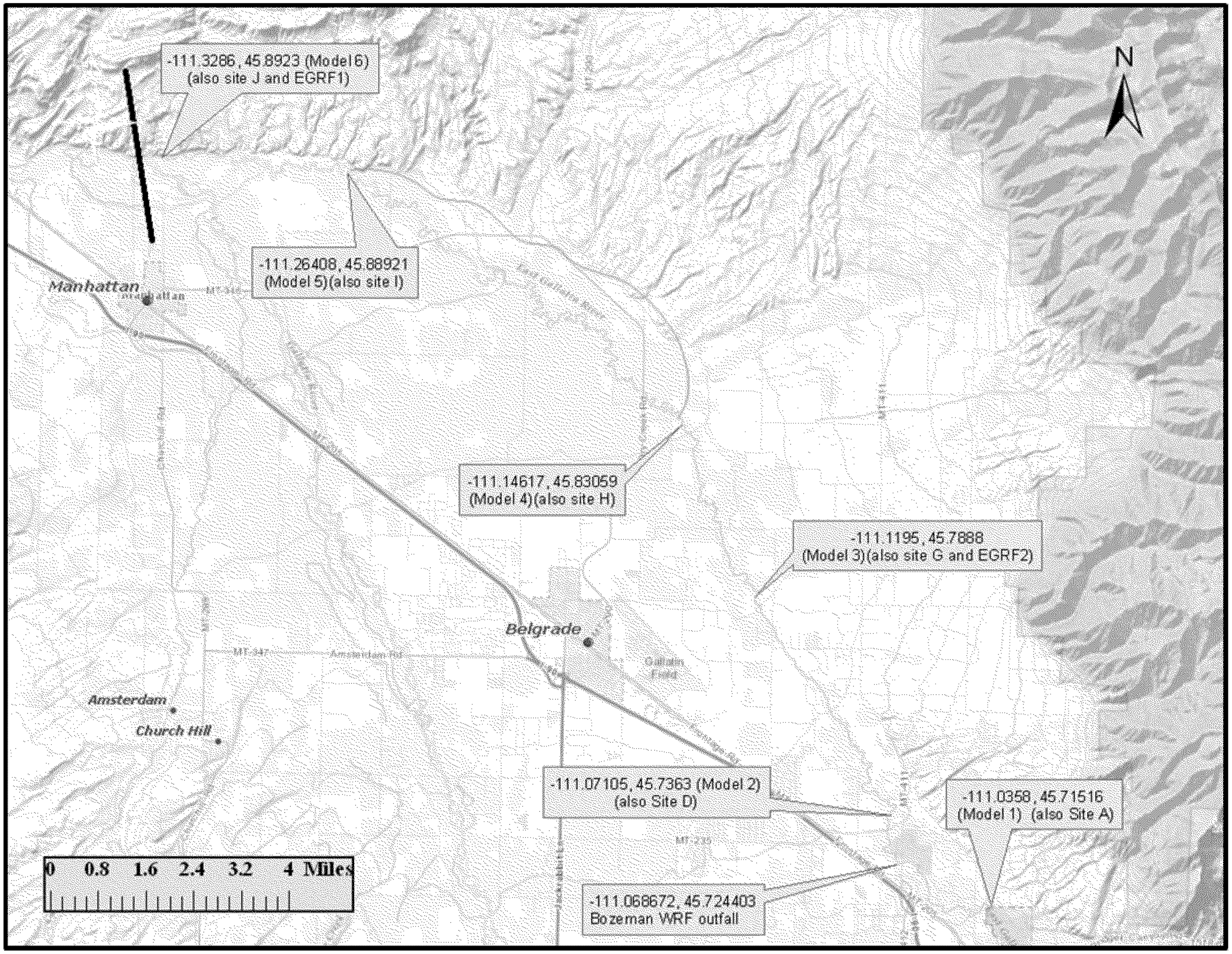

Figure 3-1. Map showing the six main sites along the East Gallatin River needed for the development of the QUAL2K model. Twelve other sampling sites (tributaries, irrigation canal withdrawals, etc.) are needed to develop the model but are not shown on this ma p.

The sites are:

Model Site 1 (~0.7 miles downstream of the Bridger Creek confluence, at 45.71516, -111.0358; same as Site A): Establishes water quality boundary conditions near the upper-most point of interest on the East Gallatin River based on reasons provided previously (page 9).

Model Site 2 (~0.3 stream miles downstream of the Riverside Water & Sewer District ponds, at 45.7363, -111.07105; same as Site D): For the purposes of the model, this site is intended to represent conditions in the East Gallatin River after the full mixing of Bozeman's WRF effluent discharge and any effects that may be coming from the Riverside Water & Sewer District ponds (see **Figure 2-3**).

Model Site 3 (upstream of confluence with Hyalite Creek, at 45.7888, -111.1195 [same as site G and site EGRF2]): Establishes water quality conditions in the East Gallatin River just before the confluence of Hyalite Creek, which naturally has differing nutrient concentrations (Suplee and Watson, 2012). This site corresponds to a site established in an earlier study (PBS&J, 2011). Any earlier data and flow-stage relationships can be compared to that collected for this study.

Model Site 4 (just upstream of the Dry Creek Irrigation withdrawal, at 45.83059, -111.14617, same as site H): Nutrient criteria recommended for Hyalite Creek are higher for TP (due to natural geologic sources) and slightly lower for TN (to maintain N limitation) than the reach of the East Gallatin River into which Hyalite flows (Suplee and Watson, 2012). As such, Hyalite Creek is an important water quality change point. Model Site 4 is intended to discern changes resulting from Hyalite Creek, and characterize the East Gallatin just prior to the Dry Creek irrigation withdrawal.

Model Site5 (just upstream of the Dry Creek Irrigation System return flow, at 45.88921, -111.26408, same as site I): The Dry Creek Irrigation system is one of if not the largest irrigation withdrawals on the East Gallatin River. Irrigation return flows can be a significant source of nutrients and turbidity. The intent of this site is to characterize the East Gallatin River just prior to the addition of irrigation return flow to the river. Changes in water quality as a result of this inflow will be captured by the next site downstream, model site 6.

Model Site 6 (just upstream of the confluence with the West Gallatin River, at 45.8923, -111.3286 [same as site J and site EGRF1]): This site is located just upstream of the confluence with the West Gallatin River, and should reflect any effects from the Dry Creek irrigation return. The site corresponds to an earlier study site (EGRF1; PBS&J, 2011) and flow-stage relationships established there can be used; it also is the end of the modeled reach.

3.2 Additional Sites Requiring Flow and Water Quality Data

Proper quantification of the water balance, associated mass fluxes, and water quality changes resulting from inputs and outputs to the East Gallatin River are key to a successful modeling strategy. As a result, there are a number of large and small tributaries inflows, irrigation withdrawals and return flows, and point source contributions that need to be quantified. These should be sampled for concentrations of nutrients (total nitrogen, nitrate+nitrite, ammonia, total phosphorus, and soluble reactive phosphorus), TOC, alkalinity, TSS and ISS, hardness, and $CBOD_{20}$ along with instantaneous measurement of temperature, DO, conductivity, pH, and flow.

A list of important hydrologic features that the Department believes should be characterized is shown below. Other tributaries and canals may be included if greater model detail is desired:

1. Bozeman WRF effluent

2. Withdrawal to Buster Gulch irrigation diversion, located ~0.6 upstream of Site E (see **Figure 2-1**); flow only

3. Mouth of Hyalite Creek

4. Withdrawal to Dry Creek irrigation diversion, just downstream of model site 4 (flow only)

5. Mouth of Smith Creek

6. Mouth of Dry Creek

7. Mouth of Ben Hart Creek

8. Mouth of Story Creek

9. Mouth of Cowen Creek

10 Mouth of Gibson Creek

11. Return flow from Dry Creek irrigation diversion (just downstream of model site 5)

12. Mouth of Thompson Creek

13. Mouth of Bull Run Creek

It should be noted that prior to the field assessment, diurnal variation of the discharge of the wastewater from the Bozeman WRF should be considered. If flows from the WRF are significantly variable such that they alter the diurnal flow characteristics of the East Gallatin River itself, further discussions with the Department should be commenced about using a time-variable flow model necessary to represent these changes and their associated effect on water quality.

3.3 Other Data

In addition to the boundary conditions identified previously, forcing functions of air temperature, dewpoint, windspeed, and cloud cover are required to develop incoming PAR estimates and associated heat balances with QUAL2K. The Department has not taken the time to investigate whether suitable information is available from Gallatin Field (or other stations), but it is recommended that such information be assessed to determine availability as well as whether it is appropriate for the East

Gallatin River corridor. If suitable information is not available, it is recommended that a meteorological station be placed nearby to measure these inputs for the model.

3.4 Numeric Nutrient Criteria Derivation Process via QUAL2K

A properly calibrated and validated QUAL2K model is necessary for nutrient criteria derivation. Basic criteria for determining when the model is calibrated and validated can be found in Suplee et al. (2006) and are further elaborated upon in Flynn and Suplee (2011). Numeric nutrient criteria can be ascertained by simulating incremental nutrient additions, or more likely in this case nutrient reductions, to the point where water quality standards (e.g., DO, pH), benchmarks (benthic algae density), or other ecological indicators are in compliance /achieved. Detailed discussions of this process are found in Section 13 of Flynn and Suplee (2011).

4.0 Can Beneficial Uses be Supported by Applying Greater Emphasis on Reducing One Nutrient?

The model described in **Section 3.0** can be used to answer certain questions regardless of whether or not the East Gallatin River is found to have nuisance algae levels or other undesirable water quality characteristics. If it is established that algae density is above benchmarks, the model can be used to explore “what if” scenarios, including “what if the city of Bozeman greatly reduced its TP load to the East Gallatin but only reduced its TN load somewhat?”

Figure 4-1 helps illustrates the concept. Taken from Flynn and Suplee (2011), **Figure 4-1** shows growth limitation factors (0-1 scaling factor) from nitrogen, phosphorus, or light at any given point along the river. The horizontal line nearest to the X-axis is the most-limiting factor.

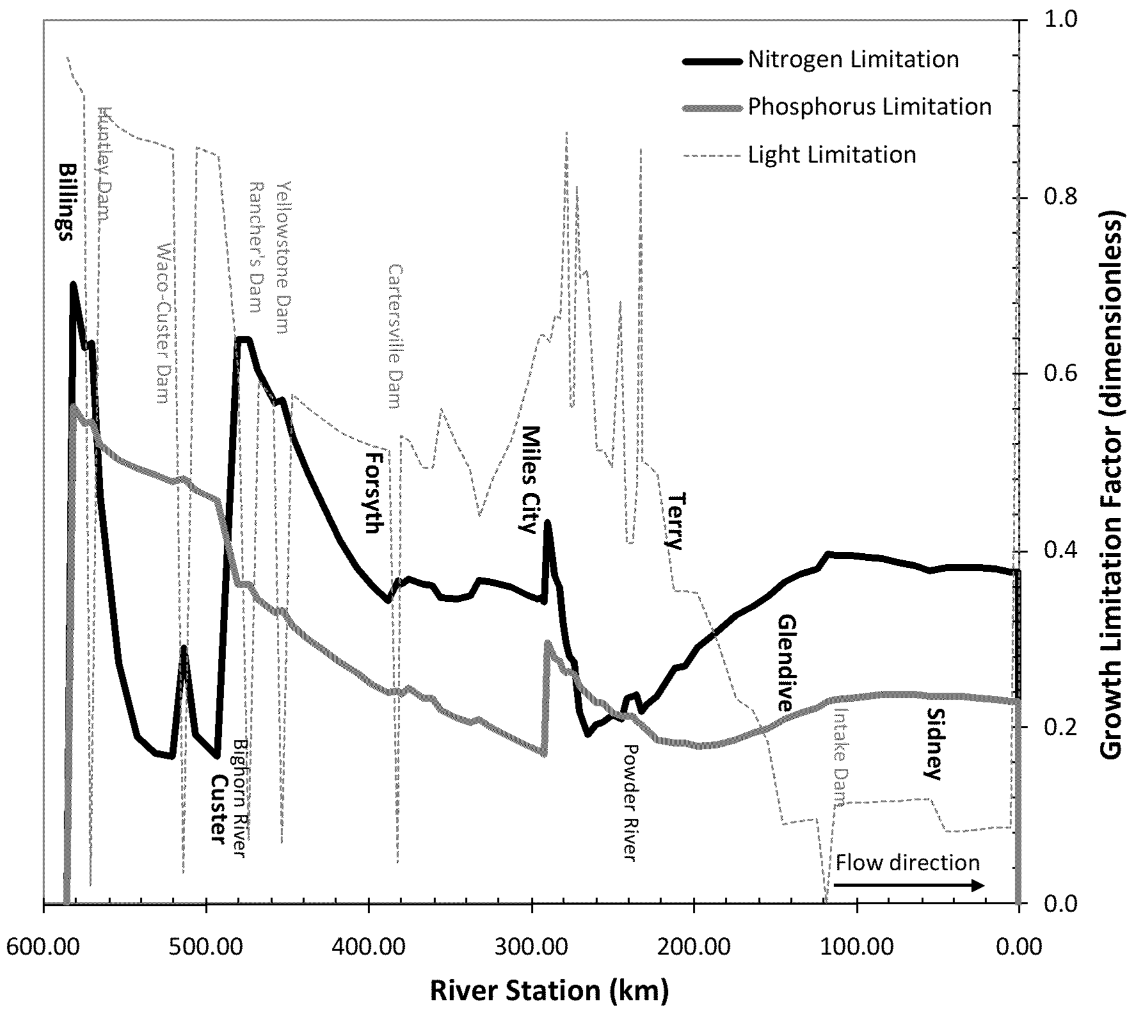

Figure 4-1. QUAL2K model results for nitrogen, phosphorus, and light limitation of benthic algae in the Yellowstone River. From Flynn and Suplee (2011).

What can be ascertained from **Figure 4-1** is that in the case of point-source inputs, the nutrient limitation term can greatly change. In this example, nitrogen limitation is strong downstream of the city of Billings for some distance due to phosphorus load additions from the Billings WWTP (note: the nitrogen load is also large, but the phosphorus load evidently has a much stronger effect because it leads to river phosphorus concentrations far above saturation levels for benthic algae). But the nitrogen-limitation status then changes due to external conditions. So within a model, questions can be posed such as: (1) “What if the Billings TP load were to be greatly reduced such that phosphorus could be made limiting (or co-limiting) with nitrogen?”, (2) “What effect would this have on benthic algae levels in the immediate vicinity of the wastewater discharge?”, and (3) “What would be the effect further downstream?”.

In the case the East Gallatin River, such an exercise would greatly help us understand if a greater reduction in WRF phosphorus (the less expensive nutrient to eliminate) would achieve benthic algae targets by pushing the East Gallatin to P limitation. The model could also be used to see the downstream effects. We know that Hyalite Creek introduces naturally-elevated TP concentrations; in all probability, any TP limitation achieved further upstream would there be lost. The model could also show how changes to WRF treatment systems affect benthic algae. Model results may possibly indicate that a substantial reduction in TN from the WRF is necessary so that nitrogen limitation (and beneficial uses) can be maintained below the Hyalite Creek confluence. Again, the main point is that with the QUAL2K model "what if" scenarios can be evaluated.

5.0 Status Monitoring

If reach specific criteria are developed and it appears that downstream uses will be protected, and those criteria are moving towards adoption by the Board of Environmental Review, the last step in the process is status monitoring. The state-of-the-art in both mechanistic and empirical models is such that they inherently have noise, and confirmation of use-support of the reach-specific criteria is needed to assure stream protection. It is recommended that model sites 1 through 6 be used for this purpose regardless of the method used (mechanistic model or empirical model) to develop the criteria. Data collection should focus on the endpoints of concern (benthic algae density, macroinverebrate metrics, diatom metrics), and (if QUAL2K modeling was used) other endpoints (like pH) that were used in developing the criteria. Presuming that the criteria can be met by changes to the WRF alone, then, after upgrades occur, five years continuous monitoring is recommended at a minimum, to be carried out by the city or its consultants. Five years will also allow enough time to apply robust non-parametric trend statistics to the dataset (Helsel and Hirsch, 2002). Models developed via the methods outlined in **Sections 2.6 and 3.0** may show that, due to nonpoint source contributions, an upgrade to the WRF cannot in and of itself achieve the reach-specific criteria. In this case, the Department and the city should discuss how to proceed with status monitoring. TMDLs for nonpoint source cleanups or application of BMPs generally recognize that implementation will take years (5+), and this should play an important role in determining the monitoring status timeline.

6.0 Budget Estimates

An estimate was made for the cost to complete the data collection and analysis for each of the three major aspects discussed: (1) the biological characterization, followed by either (2) empirical statistical modeling or (3) QUAL2K modeling. Estimates shown are total, that is, the grand total to complete each task including development, calibration, and validation of the models, and any criteria developed thereof. Status monitoring, which would occur afterwards, is not included. Cost estimates were based on 2012 analytical laboratory price sheets, costs for purchasing small equipment or rental of large equipment, etc. They should be viewed as estimates only, as best professional judgment was needed to estimate hours of labor for field data collection, professional data analysis and modeling, etc. See **Appendix A** for details.

1. Biological characterization: $75,220

The following are additional costs to be added to that above in order to complete the task:

A. Empirical Model Approach: $30,900
B. QUAL2K Model Approach: $113,635

If the empirical approach is taken, the grand total (biological characterization plus the empirical statistical model) is $106,120. If the minimized study (sites B, D, F, G, H, I and J only) is selected for the empirical approach, which again includes the biological characterization, the grand total drops to $75,853. If the mechanistic model approach using QUAL2K is taken, the grand total (biological characterization plus the calibrated and validated model) is $188,855. If the minimized study (sites B, D, F, G, H, I and J only) is selected for the biological characterization, the grand total for the QUAL2K model approach drops to $168,500.

7.0 Next Steps

This document has outlined the basic conceptual framework for (a) characterizing the biological and water-quality status of the East Gallatin River (**Section 2.0**), (b) using empirical methods to derive the criteria (**Sections 2.6**), (c) using mechanistic modeling approaches to derive the criteria (**Section 3.0**), (d) consideration of downstream effects (**Sections 2.7 and Section 4.0**), and (e) biological status monitoring (**Section 5.0**). This document provides several pathways and options to study and model the East Gallatin River.

If work outlined in this document is to be undertaken, the next logical step would be to develop a detailed SAP. Potentially, a Quality Assurance Project Plan (QAPP) may need to be developed, but that document may be optional so long as Department SOPs are closely adhered to and the SAP provides sufficient detail on topics that are not specifically covered in DEQ SOPs. Further discussion with the Departments Quality Control Officer (Mindy McCarthy; MMcCarthy3@mt.gov) should clarify if a QAPP is needed to further support field sampling. If reach-specific criteria are found to be needed and the QUAL2K model is going to be used, it would be worth further consultation with the Department on a QAPP specific to the model as well as discussions with Department staff during model development.

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Appendix A

1. Biological Characterization (2-year study, up to three months per summer). This work is undertaken regardless of preferred modeling approach.

	Benthic Algae (Chl*a*)		Benthic Algae (AFDM)		Macroinvertebrates		Diatoms		WQ (nutrients, TSS)*		Herbicides**	
SITE	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample
A	6	$1,170	6	$300	4	$980	2	$500	6	$960.00	5	$750
B	6	$1,170	6	$300	4	$980	2	$500	6	$960.00	5	$750
C	6	$1,170	6	$300	4	$980	2	$500	6	$960.00	5	$750
D	6	$1,170	6	$300	4	$980	2	$500	6	$960.00	5	$750
E	6	$1,170	6	$300	4	$980	2	$500	6	$960.00	5	$750
F	6	$1,170	6	$300	4	$980	2	$500	6	$960.00	5	$750
G	6	$1,170	6	$300	4	$980	2	$500	6	$960.00	5	$750
H	6	$1,170	6	$300	2	$490	1	$250	6	$960.00	5	$750
I	6	$1,170	6	$300	2	$490	1	$250	6	$960.00	5	$750
J	6	$1,170	6	$300	2	$490	1	$250	6	$960.00	5	$750
Totals:		$11,700		$3,000		$8,330		$4,250		$9,600		$7,500
Subtotals, analytical costs:	$44,380											
YSI 6600 Sonde Rental:	$2,240	Assume 2 sondes, deployed for 1 week each summer for two summers ($560 X 2 X 2).									* TSS	$20.00
Purchase YSI 85	$1,350	For instantaneous DO, temperature, and conductivity. Separate low-cost pH meter can be purchased.									TN	$40.00
Labor in field:	$14,250	Assume a field team of 2 people, 10 sites, 3 hrs/site, average of 4.75 trips per site (for both years), assume $50/hr.									TP	$30.00
Data analysi:s	$10,000	Assume 1 person, contracted, professional environmental consulting firm									SRP	$30.00
Misc. supplies:	$3,000	macroinvertebrate nets, filters, filter apperatus, vehicle gasoline, etc.									nitrate + nitrite	$25.00
GRAND TOTAL, Biological Characterization:	**$75,220**										total ammonia	$15.00
				Analytical (min sites)	Field labor (min sites)							$160.00
				$28,300	$9,975			GRAND TOTAL, min. sites (B, C, F, G, H, I, J):		$54,865		
						**N, P, and S containing pesticides (Method E507 modified).						

2. Statistical Empirical Model (One additional year of data in additional to the biological characterization).

	Benthic Algae (Chl*a*)		Benthic Algae (AFDM)		Macroinvertebrates		Diatoms		WQ (nutrients, TSS)*		Herbicides	
SITE	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample	Frequency	Cost/sample
A	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
B	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
C	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
D	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
E	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
F	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
G	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
H	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
I	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
J	3	$585	3	$150	2	$490	1	$250	3	$480.00	2	$300
Totals:		$5,850		$1,500		$4,900		$2,500		$4,800		$3,000

Subtotals, analytical costs:	$22,550	
YSI 6600 Sonde Rental:	$560	Assume 1sondes, deployed for 1 week for 1 summers ($560 X 1 X 1).
Labor in field:	$6,990	Assume a field team of 2 people, 10 sites, 3 hrs/site, average of 2.333 trips per site, assume $50/hr.
Data analysi:s	$15,000	Assume 1 person, contracted, professional environmental consulting firm. This would be final report and emperical model development
Misc. supplies:	$800	macroinvertebrate nets, filters, filter apperatus, vehicle gasoline, etc.
Year 3 Total:	$30,900	
Emperical Model, TOTAL ‡:	**$106,120**	

Analytical (min sites)	Field labor (min sites)	Year 3 Total, min. sites (B, C, F, G H, I, J):
$14,735	$4,893	$20,988

Emperical Model, TOTAL, min sites (B, C, F, G, H, I, J) ‡: $75,853

3A. QUAL2K Model main sites (data in addition to data from the biological characterization). Assumes a single year sampling in Aug and Sept.

SITE	Benthic Algae (Chl*a*) Frequency	Benthic Algae (Chl*a*) Cost/sample	Benthic Algae (AFDM) Frequency	Benthic Algae (AFDM) Cost/sample	Phytoplankton Chl*a* Frequency	Phytoplankton Chl*a* Cost/sample	Nutrients* Frequency	Nutrients* Cost/sample	TSS, ISS, Alk, Hardness, TOC† Frequency	TSS, ISS, Alk, Hardness, TOC† Cost/sample	$CBOD_{20}$ Frequency	$CBOD_{20}$ Cost/sample
1 (same as A)	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
2 (same as D)	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
3 (same as G)	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
4 (same as H)	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
5 (same as I)	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
6 (same as J)	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Totals:		$2,340		$600		$780		$1,260		$720		$720
							*TN	$40.00		†TSS	$20	
							TP	$30.00		ISS	$20	
							SRP	$30.00		alkalinity	$10	
							nitrate + nitrite	$25.00		hardness	$20	
							total ammonia	$15.00		TOC	$35	
							total nutrients:	$140.00		*total WQ:*	$105.00	

3B. QUAL2K Model, Additional Sites. Assumes a single year sampling in Aug and Sept.

Additional Sites	Benthic Algae (Chl*a*) Frequency	Benthic Algae (Chl*a*) Cost/sample	Benthic Algae (AFDM) Frequency	Benthic Algae (AFDM) Cost/sample	Phytoplankton Chl*a* Frequency	Phytoplankton Chl*a* Cost/sample	Nutrients* Frequency	Nutrients* Cost/sample	TSS, ISS, Alk, Hardness, TOC† Frequency	TSS, ISS, Alk, Hardness, TOC† Cost/sample	$CBOD_{20}$ Frequency	$CBOD_{20}$ Cost/sample
(two flow sites)												
Bozeman WRF	0	$0	0	$0	0	$0	3	$420.00	3	$315	3	$180
Hyalite Cr mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Smith Cr mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Dry Creek mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Ben Hart Cr mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Story Cr mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Cowen Cr mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Gibson Cr moutn	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Dry Creek Irrig. return	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Thompson Cr mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Bull Run Cr mouth	2	$390	2	$100	2	$130	2	$280.00	2	$210	2	$120
Totals:		$3,900		$1,000		$1,300		$3,220		$2,415		$1,380
Subtotals, analytical costs:	$19,635											
YSI 6600 Sonde Rental:	$10,800	Assume 6 sondes, deployed for 2 weeks in Aug and 2 weeks in Sept ($1800/month X 6).										
Labor in field:	$12,000	Assume a field team of 2 people, 16 sites, 3 hrs/site, average of 2.5 trips per site (for both months), assume $50/hr. Assume flow meter provided by consultant.										
Hobo Weather Station:	$1,200											
Data analysi:s	$65,000	To build calibrated and validated model, professional environmental consulting firm with expertise in QUAL2K modeling										
Misc. supplies:	$5,000	vehicle gasoline, filters, syringes, Aquarods, etc., contingencies										
QUAL2K Model, TOTAL:	**$113,635**											